

PRELIMINARY EXPERIMENTS ON THE CHARACTERISTICS AND POTENTIAL USES OF COAL FLY ASH FROM ISRAEL.

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INTRODUCTION

Traditionally electric power in Israel has been produced from heavy fuel oil. Starting in 1982, the government-owned electric utility began to build coal-fired power stations and about 55% of the current output is now derived from coal. The switch to coal was made for strategic, economic and environmental reasons and future plans call for a continuing replacement of oil by coal for power generation.



Figure 1. Location of Power Stations

All power stations in Israel are on the Mediterranean coast (as shown in Figure 1) due to the need for copious supplies of cooling water which are unavailable elsewhere in the country. The coastal plain of Israel contains a large shallow aquifer which supplies a considerable part of the country's potable water. Most of the population is concentrated in this part of the country and this aquifer is already in considerable danger from anthropogenic pollution. Hence, there is much understandable concern about the effects of dumping large quantities of extraneous material anywhere on the coastal plain. It is for this reason that coal fly ash has been declared a hazardous waste material by the Israel Ministry of the Environment who put strict controls on its disposal. The only suitable site for dumping the ash is in the Negev desert south of Beersheva, and this entails considerable transportation costs. The practice of dumping the ash at sea at carefully chosen deep sites has now been stopped.

This paper surveys the present position and describes preliminary experiments on representative samples of coal fly ash. These experiments are intended to fully characterize the properties of the ash as a preliminary step to suggesting

ways to utilize it as a useful material instead of treating it as an industrial waste.

ASH PRODUCTION AND DISPOSAL

The ash produced from the coal fired power stations has been disposed of as follows:

- Dumping in ash embankments at the Hadera power station.
- Use as an additive to cement by the Nesher Cement Co. (up to 10% allowed by the appropriate Israel Standard).
- A small amount as raw material for cement production.
- Dumping at sea (a limited amount under supervision of the Ministry of the Environment).

Table 1, reproduced from Metzger⁽¹⁾, summarizes the position - past and present.

TABLE 1

Amounts of ash produced, utilized and disposed of in Israel: Total and recent years
(thousands of tonnes)

	1993	1994	1995	1982-95
Total Production	640	650	735	6060
<u>Utilization/disposal:</u>				
Cement production	420	440	630	3910
Embankments	150	160	20	1120
Disposal at sea	70	50	85	1030

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Israel's electricity consumption is growing rapidly due to natural development and a rising standard of living and also because of the accelerated increase in population due to immigration. The current coal-fueled generating capacity is about 3,700 MW and this is scheduled to rise to 4,900 MW by the year 2000 with the addition of extra units to existing power stations. Total imports of coal for the year 1996 were about 7.5 million tonnes and of this all but 30,000 tonnes was used for electricity generation. As long term plans for electricity production are linked to coal, it is obvious that the amount of ash produced will increase and the problem of its disposal will become more acute. Ash production is expected to be 1,000,000 tonnes in 1997 and to reach 1,300,000 tonnes by the year 2001. In the year 2001 ash production will exceed the current level of utilization by approximately 700,000 tonnes. As the amount of ash used by the cement industry is near saturation, new uses must be developed, old uses expanded or the material must be exported if the undesirable prospect of ash disposal is to be avoided.

At present there are no flue gas desulfurization (FGD) plants on any of the coal fired power stations in Israel, so the potential problems of disposing of the by-products of such plants will not be considered here. However, FGD units will be erected in the Ashkelon power station by the year 2001 and subsequently may also be retrofitted in the Hadera power station.

EXPERIMENTAL and RESULTS

The Israel Ash Authority recently collected two carefully homogenized samples of fly ash for a study of the environmental effects of ash disposal and these were also used for the present study. These samples were chosen to represent the two main types of fly ash produced in Israel according to the type of coal burnt. The samples are designated as South African (SA) and Colombian (CO) after the (approximate) source of the parent coal.

Aqueous extracts of the fly ash samples are strongly alkaline (approximately pH 12 to 12.5) and the major chemical composition of the ashes is shown in Table 2⁽³⁾.

TABLE 2
Analyses of reference samples of South African and Colombian Fly Ash

Element	South African %	Colombian %
SiO ₂	44.0	56.5
Al ₂ O ₃	33.2	23.5
TiO ₂	1.8	1.2
Fe ₂ O ₃	2.9	6.5
CaO	9.5	4.0
MgO	2.2	1.5
SO ₃	0.8	0.6
P ₂ O ₅	1.5	0.8

The samples were dry sieved into four fractions as shown in Table 3 and the carbon content of the fractions determined. The individual fractions were examined under both optical and scanning electron microscopes and the mineralogical properties of each fraction determined by X-ray diffractometry (XRD).

Table 3 shows the proportions of the various fractions present and the amount of carbon in each.

TABLE 3
Size fractions of the ash components and their carbon contents

Size		South African		Colombian	
Fraction	micron	%	carbon %	%	carbon %
>100 mesh	>150 μ	1.9	24.6	4.5	46.8
100-200	150-75	8.2	13.7	10.0	16.2
200-325	75-45	51.6	2.88	55.0	4.21
<325	<45	38.3	1.91	30.5	3.03

The original samples and the various fractions were examined under the optical microscope and the proportions of the following components determined: glass, mullite, spinel, quartz, isotropic coke, anisotropic coke and inerte. The predominant component (>90%) in both samples is glass. The total amount of carbon determined by this method for the original samples was 5.0% for SA and 7.4% for CO. These values compare with 4.2% and 7.1%, respectively, determined by a chemical method. Microscopic examination also shows that there is considerably more anisotropic coke (as defined by optical activity) present in the CO sample than in the SA sample.

Examination under the scanning electron microscope showed that the samples are typical fly ashes composed mainly of small aluminosilicate spheres. The carbon particles are relatively large and are porous with many glass spheres embedded in the interstices (Figure 2).

XRD spectra of the two samples showed some distinct differences. These were originally thought to be related to the presence of graphitic domain structures in the CO sample, but this aspect of the work needs further investigation. The graphitic character of anisotropic coke in fly ash has been commented on previously by Graham *et al.*⁽³⁾. The other minerals identified by XRD were: quartz, mullite and traces of lime.

DISCUSSION

The first step in any plan to encourage the use of fly ash as a raw material must be to supply a standard product with well defined properties. This product should conform to existing national or international standards. Perhaps the foremost of these is ASTM C 618⁽⁴⁾ which relates to the use of fly ash as a pozzolanic additive to Portland cement. This is an end use with a particularly high added value and Israeli ash is already used to some extent for this purpose. However, larger additions of fly ash to cement are quite common and, on the whole, improve the properties of the finished product. When the materials are examined on a size basis, distinct differences in the chemical and physical characteristics of the ash are found. These differences suggest that the separation of the ash into two fractions, a coarse +200 mesh (>75 μm) and a fine -200 mesh (<75 μm), would result in more usable products.

Carbon is preferentially fractionated to the larger sizes. The concentration of carbon found in the coarsest fraction of the material (+100 mesh or >150 μm) is probably sufficient to sustain combustion and may be recycled to the furnace to recapture its fuel value and increase overall fuel efficiency. The coarse fraction could also be further processed to concentrate the carbon for high value uses such as an adsorptive carbon as suggested by Graham *et al.*⁽⁵⁾.

Carbon, however, is undesirable in fly ash used as a cement additive in concrete. It reacts with air entrainment reagents, is non-pozzolanic and may color the concrete if present in high enough concentrations. Because of these characteristics the loss on ignition (LOI), which for the most part is carbon, is limited by the ASTM C-618 standard to 6%. The fine fraction (-200 mesh or 75 μm) of both samples would easily meet this criterion. This may allow the proportion of fly ash currently used in cement in Israel to be increased beyond the current 10%. A substitution of 16% to 20% is typical for fly ash used in the U.S. The classification of the ash may also improve its pozzolanic properties. This would make it a more desirable material and encourage the development of an international export market.

The other suggested high volume use for fly ash is as a light-weight aggregate for building blocks. These could serve as a substitute for the no-fines concrete blocks which are now ubiquitously used, with the additional advantage of reducing the amount of quarrying and crushing needed for aggregate production.

Some other possible uses of fly ash are:

- as a light weight aggregate for aerated insulating building blocks.
- as a low strength flowable fill for trenches and around building foundations and basements.
- as the sand component of cement - Israel has a shortage of sand for concrete production in the densely populated parts of the country.

All these potential applications would be more profitable than using the fly ash as road-bed material and would be without the possible ecological disadvantages of this use.

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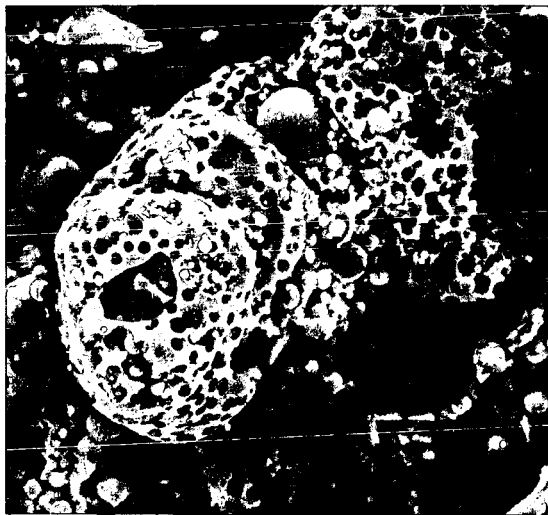


Figure 2. Porous carbon particle with embedded aluminosilicate spheres
(Photomicrograph size approx. 80 x 80 μm)